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Maximal Stimulation of Myofibrillar Protein Synthesis Requires a Higher Relative Protein Intake in Healthy Older versus Younger Men

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Abstract

Background: Regular periodic stimulation of postprandial myofibrillar protein synthesis (MPS) is critical to maintain skeletal muscle mass, especially in older adults.

Objective: Although dietary protein ingestion enhances MPS, it is unclear what the relative protein intake is to maximize the response in older adults and whether it may differ from that of younger adults.

Participants and Design: We retrospectively analyzed data from our laboratories that measured MPS in healthy older (~71y) and young (~22y) men by primed constant infusion of L-*ring*-[$^{13}C_6$]phenylalanine after ingestion of varying amounts (0-40g) of high quality dietary protein as a single bolus and normalized to body mass.

Results: There was no difference (P=0.53) in basal MPS rates between older (0.027±0.04%/h; means±95% CI) and young (0.028±0.03%/h) men. Bi-phase linear regression and breakpoint analysis revealed that slope of first line segment was different ($P < 0.05$) between ages and that MPS reached a plateau after ingestion of 0.40±0.19g/kg body mass in older and 0.24±0.06g/kg body mass in younger adults (P=0.055).

Conclusion: These data are the first to characterize the relative (to body weight) protein ingested dose-response of MPS in younger and older subjects. Our data suggest that healthy older men require a greater relative protein intake, in a single meal, than young men to maximally stimulate postprandial rates of MPS. These results should be considered in protein intake guidelines for aging persons and when developing nutritional solutions to maintain or enhance muscle mass with advancing age.

Introduction

Skeletal muscle protein synthesis is a nutritionally-responsive process that is robustly stimulated by dietary protein ingestion.[1,2] The ability to stimulate postprandial protein synthetic rates, especially of the contractile myofibrillar protein fraction, determines to a large extent changes in muscle mass in a variety of healthy and diseased populations.[3] Notably, older adults have an attenuated muscle protein synthetic response after the ingestion of dietary protein and amino acids, particularly of lower quantities of protein[4,5]; this 'resistance' to the usually anabolic effect of protein on myofibrillar protein synthesis (MPS) may in part underpin an age-related decline in muscle mass.

Protein recommendations are usually provided relative to body mass, however, studies evaluating the effect of protein ingestion on the stimulation of postprandial MPS rates have reported absolute doses of protein.[1,2,6,7,8] This experimental approach may not reveal subtle physiological differences between populations (e.g. young and older adults) and limits the application of these data to provision of dietary recommendations with respect to individuals of varying body mass. Despite these potential limitations, we are aware of no study that has evaluated whether acute protein recommendations to maximally stimulate postprandial MPS can be made relative to body weight. Therefore, we performed a retrospective analysis of studies from our laboratories[1,2,6,7,8] that used similar stable isotope amino acid tracer methodologies with bolus protein ingestion of varying absolute quantities to determine the relative protein requirement to maximize the stimulation of postprandial MPS under resting conditions. In addition, comparison of healthy older and young adults was performed to determine whether aging affected the

single meal protein requirement to maximize the increase in MPS. We hypothesized that younger men would have a lower relative requirement for protein to maximally stimulate MPS than older men.

Methods

Six previous studies that measured MPS over a 3-4h postprandial period in response to the ingestion of absolute protein intakes ranging from 0-40g (corresponding to the equivalent of 0-0.64g protein/kg) were selected[1,2,6,7,8] (Witard et al., unpublished). All studies were approved by the respective local ethics committees of McMaster University, and the Universities of Stirling and Birmingham. All subjects gave their written informed consent prior to participation. Participants were healthy young or older males (Table 1) who were studied in the postabsorptive state having refrained from physical activity for at least 48 h. Participants provided voluntary, informed consent and all studies carried local ethics approval, as previously indicated.[1,2,6,7,8] To yield the greatest homogeneity in the datasets studies that provided high quality, rapidly digested, animal-based proteins (i.e. whey, n=5 studies, and egg, n=1 study) as a single bolus were included in the analysis. This selection was made since both the amino acid composition and digestion rate of ingested protein can influence the extent of postprandial MPS.[9] In addition, from the studies that involved an exercise[7] or disuse stimulus[6] only the pre-intervention resting basal and fed-state responses were included.

To capture the peak postprandial aminoacidemia, MPS was measured over the first 3-4h after protein ingestion using a primed constant infusion of L-*ring*-

67 [$^{13}C_6$]phenylalanine. Plasma and intracellular [$^{13}C_6$]phenylalanine enrichments were
68 determined by gas chromatography-mass spectrometry and protein bound enrichment by
69 gas chromatography-combustion-isotope ratio mass spectrometry. MPS rates (%/h) were
70 determined using the standard precursor-product approach with either intracellular[1,2,6,7,8]
71 or corrected plasma [assuming a standard intracellular to plasma phenylalanine
72 enrichment ratio of 0.81[10]] phenylalanine enrichment (Witard et al., unpublished) as the
73 precursor. Basal MPS was determined using the single biopsy approach[1,2,6,7,8], as
74 previously described.[11,12]

75 Differences in subject characteristics and basal MPS between the older and
76 younger adults were analyzed using a Student's independent paired T-test. To determine
77 the dose-response relationship between protein intake and muscle protein synthesis, MPS
78 was plotted against the ingested protein dose normalized to both body mass (BM) and
79 lean body mass (LBM; measured by dual-energy X-ray absorptiometry, where available
80 [8,6,2]; Witard et al. unpublished) and analyzed by fitting linear and bi-phasic linear
81 regression to determine a model of best fit. With the slope of the second portion of the bi-
82 phasic linear regression constrained to zero, the average protein intake to maximize
83 postprandial MPS (and associated 95% CI) was determined by breakpoint analysis. The
84 slope of the first portion of the bi-phasic linear regression and the breakpoint was
85 compared between young and older adults to determine age-related differences.
86 Regression data were analyzed using Prism V5.0 (GraphPad Software Inc, La Jolla, CA,
87 USA). Significance was accepted at $P<0.05$ with data presented as means ± 95% CI.
88

Results

There were no differences in BM and BMI between the older and younger adults (Table 1). However, LBM, which was only available for a subset (n = 43) of young men, was greater ($P < 0.01$) than in the older adults. There was no difference ($P = 0.53$) in basal rates of myofibrillar protein synthesis between the groups.

Analysis revealed that bi-phasic linear regression models of the relationship between myofibrillar FSR and ingested protein dose (expressed per kg of BM) explained significantly greater proportions of variance versus simple linear regression models in younger ($r^2 = 0.49$ versus 0.43, respectively; $P<0.01$) and older ($r^2 = 0.44$ versus 0.34, respectively; $P<0.05$) men. Similar results were also obtained when the data were expressed relative to LBM for a subset (n=44) of the younger ($r^2 = 0.34$ and 0.22, respectively; $P<0.01$) and all of the older ($r^2 = 0.41$ and 0.35, respectively; $P<0.05$) men. Collectively, these results indicate that the data conformed to a saturatable dose-response relationship.

Breakpoint analysis of the bi-phasic models showed that the protein intake required to maximally stimulate MPS in the older (0.40g/kg BM, CI: 0.21-0.59) tended to be different (P=0.055) than the younger adults (0.25g/kg BM, CI: 0.18-0.30; Figures 1A and B). The difference in breakpoints was significant ($P<0.01$) when expressed relative to LBM in the older (0.60g/kg LBM, CI 0.32-0.89) and a subset (n=44) of younger (0.25g/kg LBM, CI 0.12-0.38) adults (data not shown). In addition, the slopes of the first portion of the bi-phasic linear regression curves were significantly different ($P<0.05$) between the older compared to the younger men (older: 0.071(%/h)/(g/kg BM), CI 0.039-

0.103; younger: 0.119(%/h)/(g/kg BM), CI 0.083-0.155) and LBM (0.047(%/h)/(g/kg LBM), CI 0.026-0.069; younger: 0.127(%/h)/(g/kg LBM), CI 0.039-0.215).

Discussion

The aetiology of sarcopenia is multifactorial;[13] however, declines in skeletal muscle mass would ultimately result from an imbalance between the rates of muscle protein synthesis and breakdown. Typically, declines in muscle mass precede decrements in muscle force and/or performance,[14] which reinforces the importance of determining appropriate nutritional (and/or exercise) interventions to maintain skeletal muscle mass with age. The stimulation of muscle protein synthesis requires protein ingestion and is dependent on protein quality, quantity, and sensitivity of the skeletal muscle to the subsequent hyperaminoacidemia.[9] A preponderance of evidence now suggests that aging results in skeletal muscle protein synthesis becoming relatively refractory to the normally anabolic stimulus of hyperaminoacidemia, particularly at lower protein intakes.[5] To maintain skeletal muscle mass and quality with aging it is important to consume adequate protein to support a robust postprandial stimulation of MPS. Our data demonstrate, for the first time, that the relative quantity of ingested protein required to maximize MPS is greater in older as compared to younger men. Our data lend some support to recent recommendations that optimal protein intakes for older persons could be higher than the US-Canadian Recommended Dietary Allowance for protein.[4,15]

Consistent with previous observations[16], we found similar rates of postabsorptive MPS in older and younger men suggesting that the gradual loss of muscle mass with

advancing age is not related to an overt dysregulation of postabsorptive MPS in healthy adults. In addition, maximal postprandial rates of MPS were generally similar between the young and older adults in the present study (~0.058 and ~0.056%/h, respectively; Figure 1) suggesting healthy elderly muscle retains the capacity for enhanced rates of MPS with sufficient nutritional stimulation.[17,18,19] However, we observed a 'rightward' shift of the breakpoint and a lower slope of the first component of ingested protein dose-MPS response curve, which are indicative of a reduced sensitivity of elderly muscle to ingested dietary protein. This 'anabolic resistance' of MPS with aging is not without precedence[5] and may be related to factors such as a dysregulation of intracellular signalling (e.g. mTOR),[20,21] a reduction in postprandial nutritive blood flow,[22,23] development of sub-clinical chronic inflammation,[24] a greater splanchnic extraction,[25,26] and/or a reduction in habitual activity.[6]

Our observation that healthy older adults require ~0.39g/kg of protein as a single bolus to maximally stimulate MPS may explain in part the greater retention of lean mass over a 3-y period in free-living older adults consuming relatively higher (i.e. ≥1.2g/kg/d) versus lower (i.e. ~0.8g/kg/d) protein intakes.[27] In contrast to the typically unbalanced daily distribution of dietary protein that is common in older adults in Western societies[28], it has been suggested 3 balanced daily meals (breakfast, lunch, and dinner) would optimally stimulate muscle protein synthesis and is consequently the most efficient means to consume the daily protein intake.[29] If one assumes that a balanced protein distribution is most favourable for skeletal muscle anabolism, then collectively the present data, and that of others,[27] suggest that older adults require a greater dietary protein intake (i.e., 3

155 times 0.40g/kg or ~1.20g/kg/d based on the present data) than their younger peers to
156 optimally stimulate MPS and maintain muscle mass with advancing age.[4,15]

157 The present study provides estimates of the relative protein intake required to
158 maximize the stimulation of postprandial MPS after the ingestion of a high quality,
159 rapidly digested animal-based protein in healthy young and older men. However, the
160 present dataset could be considered unique to the conditions studied as we speculate that
161 physiological and/or dietary factors could impact the acute protein requirements to
162 optimally enhance postprandial muscle anabolism. These factors could include, for
163 example, prior contractile activity,[7,23] and/or consumption of leucine-enriched
164 proteins,[30,31] which could cause a 'leftward shift' of the breakpoint of the protein dose-
165 response and lower protein requirements for optimal stimulation of MPS. In contrast,
166 muscle disuse,[6,32,33] disease status,[24] and/or lower quality protein (with lower leucine
167 content)[30,34] would likely increase (i.e., induce a 'rightward shift') relative protein
168 requirements, regardless of age. Therefore, future work is required to determine to what
169 extent the present 'optimal' protein intake can be translated to other populations (e.g.
170 healthy/diseased, women) and under different nutritional conditions (e.g. protein source,
171 macronutrient co-ingestion, digestion rate, etc.).

172

173 **Conclusion**

174 The present data provide a reference point from which estimates of the relative protein
175 intake to maximally stimulate postprandial rates of MPS can be made for younger
176 (~0.24g/kg) and older (~0.40g/kg) men. The protein intake references derived herein

should be considered when setting protein intakes for elderly persons and when developing nutritional strategies to maintain muscle mass.

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References

1. Moore DR, Tang JE, Burd NA, Rerecich T, Tarnopolsky MA, Phillips SM. Differential stimulation of myofibrillar and sarcoplasmic protein synthesis with protein ingestion at rest and after resistance exercise. J Physiol 2009;587:897-904.

2. Yang Y, Breen L, Burd NA, Hector AJ, Churchward-Venne TA, Josse AR, Tarnopolsky MA, Phillips SM. Resistance exercise enhances myofibrillar protein synthesis with graded intakes of whey protein in older men. Br J Nutr 2012;1-9.

3. Rennie MJ, Wackerhage H, Spangenburg EE, Booth FW. Control of the size of the human muscle mass. Annu Rev Physiol 2004;66:799-828.

4. Bauer J, Biolo G, Cederholm T, Cesari M, Cruz-Jentoft AJ, Morley JE, Phillips SM, Siegel C, Stehle P, Teta D, Visvanathan R, Volpi E, Boirie Y. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE study group. J Am Med Dir Assoc 2013;14:542-559.

5. Paddon-Jones D, Short KR, Campbell WW, Volpi E, Wolfe RR. Role of dietary protein in the sarcopenia of aging. Am J Clin Nutr 2008;87:1562S-1566S.

6. Breen L, Stokes KA, Churchward-Venne TA, Moore DR, Baker SK, Smith K, Atherton PJ, Phillips SM. Two weeks of reduced activity decreases leg lean mass and induces "anabolic resistance" of myofibrillar protein synthesis in healthy elderly. J Clin Endocrinol Metab 2013;98:2604-2612.

7. Burd NA, West DW, Moore DR, Atherton PJ, Staples AW, Prior T, Tang JE, Rennie MJ, Baker SK, Phillips SM. Enhanced amino acid sensitivity of myofibrillar protein synthesis persists for up to 24 h after resistance exercise in young men. J Nutr 2011;141:568-573.

8. Churchward-Venne TA, Burd NA, Mitchell CJ, West DW, Philp A, Marcotte GR, Baker SK, Baar K, Phillips SM. Supplementation of a suboptimal protein dose with leucine or essential amino acids: effects on myofibrillar protein synthesis at rest and following resistance exercise in men. J Physiol 2012;590:2751-2765.

9. Phillips SM, Tang JE, Moore DR. The role of milk- and soy-based protein in support of muscle protein synthesis and muscle protein accretion in young and elderly persons. J Am Coll Nutr 2009;28:343-354.

10. Baumann PQ, Stirewalt WS, O'Rourke BD, Howard D, Nair KS. Precursor pools of protein synthesis: a stable isotope study in a swine model. Am J Physiol 1994;267:E203-E209.

11. Burd NA, West DW, Rerecich T, Prior T, Baker SK, Phillips SM. Validation of a single biopsy approach and bolus protein feeding to determine myofibrillar protein synthesis in stable isotope tracer studies in humans. Nutr Metab (Lond) 2011;8:15-

12. Burd NA, Pennings B, Groen BB, Gijsen AP, Senden JM, van Loon LJ. The single biopsy approach is reliable for the measurement of muscle protein synthesis rates in vivo in older men. J Appl Physiol 2012;113:896-902.

13. Morley JE, Abbatecola AM, Argiles JM, Baracos V, Bauer J, Bhasin S, Cederholm T, Coats AJ, Cummings SR, Evans WJ, Fearon K, Ferrucci L, Fielding RA, Guralnik JM, Harris TB, Inui A, Kalantar-Zadeh K, Kirwan BA, Mantovani G, Muscaritoli M, Newman AB, Rossi-Fanelli F, Rosano GM, Roubenoff R, Schambelan M, Sokol GH, Storer TW, Vellas B, von HS, Yeh SS, Anker SD. Sarcopenia with limited mobility: an international consensus. J Am Med Dir Assoc 2011;12:403-409.

14. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinkova E, Vandewoude M, Zamboni M. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010;39:412-423.

15. Volpi E, Campbell WW, Dwyer JT, Johnson MA, Jensen GL, Morley JE, Wolfe RR. Is the optimal level of protein intake for older adults greater than the recommended dietary allowance? J Gerontol A Biol Sci Med Sci 2013;68:677-681.

16. Volpi E, Sheffield-Moore M, Rasmussen BB, Wolfe RR. Basal muscle amino acid kinetics and protein synthesis in healthy young and older men. JAMA 2001;286:1206-1212.

17. Symons TB, Schutzler SE, Cocke TL, Chinkes DL, Wolfe RR, Paddon-Jones D. Aging does not impair the anabolic response to a protein-rich meal. Am J Clin Nutr 2007;86:451-456.

18. Chevalier S, Goulet ED, Burgos SA, Wykes LJ, Morais JA. Protein anabolic responses to a fed steady state in healthy aging. J Gerontol A Biol Sci Med Sci 2011;66:681-688.

19. Katsanos CS, Kobayashi H, Sheffield-Moore M, Aarsland A, Wolfe RR. A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly. Am J Physiol Endocrinol Metab 2006;291:E381-E387.

20. Cuthbertson D, Smith K, Babraj J, Leese G, Waddell T, Atherton P, Wackerhage H, Taylor PM, Rennie MJ. Anabolic signaling deficits underlie amino acid resistance of wasting, aging muscle. FASEB J 2005;19:422-424.

21. Guillet C, Prod'homme M, Balage M, Gachon P, Giraudet C, Morin L, Grizard J, Boirie Y. Impaired anabolic response of muscle protein synthesis is associated with S6K1 dysregulation in elderly humans. FASEB J 2004;18:1586-1587.

22. Timmerman KL, Lee JL, Fujita S, Dhanani S, Dreyer HC, Fry CS, Drummond MJ, Sheffield-Moore M, Rasmussen BB, Volpi E. Pharmacological vasodilation improves insulin-stimulated muscle protein anabolism but not glucose utilization in older adults. Diabetes 2010;59:2764-2771.

23. Timmerman KL, Dhanani S, Glynn EL, Fry CS, Drummond MJ, Jennings K, Rasmussen BB, Volpi E. A moderate acute increase in physical activity enhances nutritive flow and the muscle protein anabolic response to mixed nutrient intake in older adults. Am J Clin Nutr 2012;95:1403-1412.

24. Walrand S, Guillet C, Salles J, Cano N, Boirie Y. Physiopathological mechanism of sarcopenia. Clin Geriatr Med 2011;27:365-385.

25. Volpi E, Mittendorfer B, Wolf SE, Wolfe RR. Oral amino acids stimulate muscle protein anabolism in the elderly despite higher first-pass splanchnic extraction. Am J Physiol 1999;277:E513-E520.

26. Moreau K, Walrand S, Boirie Y. Protein redistribution from skeletal muscle to splanchnic tissue on fasting and refeeding in young and older healthy individuals. J Am Med Dir Assoc 2013;14:696-704.

27. Houston DK, Nicklas BJ, Ding J, Harris TB, Tylavsky FA, Newman AB, Lee JS, Sahyoun NR, Visser M, Kritchevsky SB. Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. Am J Clin Nutr 2008;87:150-155.

28. Tieland M, Borgonjen-Van den Berg KJ, van Loon LJ, de Groot LC. Dietary protein intake in community-dwelling, frail, and institutionalized elderly people: scope for improvement. Eur J Nutr 2012;51:173-179.

29. Paddon-Jones D and Rasmussen BB. Dietary protein recommendations and the prevention of sarcopenia. Curr Opin Clin Nutr Metab Care 2009;12:86-90.

30. Tang JE, Moore DR, Kujbida GW, Tarnopolsky MA, Phillips SM. Ingestion of whey hydrolysate, casein, or soy protein isolate: effects on mixed muscle protein synthesis at rest and following resistance exercise in young men. J Appl Physiol 2009;107:987-992.

31. Pennings B, Boirie Y, Senden JM, Gijsen AP, Kuipers H, van Loon LJ. Whey protein stimulates postprandial muscle protein accretion more effectively than do casein and casein hydrolysate in older men. Am J Clin Nutr 2011;93:997-1005.

32. Drummond MJ, Dickinson JM, Fry CS, Walker DK, Gundermann DM, Reidy PT, Timmerman KL, Markofski MM, Paddon-Jones D, Rasmussen BB, Volpi E. Bed rest impairs skeletal muscle amino acid transporter expression, mTORC1 signaling, and protein synthesis in response to essential amino acids in older adults. Am J Physiol Endocrinol Metab 2012;302:E1113-E1122.

33. Glover EI, Phillips SM, Oates BR, Tang JE, Tarnopolsky MA, Selby A, Smith K, Rennie MJ. Immobilization induces anabolic resistance in human myofibrillar protein synthesis with low and high dose amino acid infusion. J Physiol 2008;586:6049-6061.

34. Yang Y, Churchward-Venne TA, Burd NA, Breen L, Tarnopolsky MA, Phillips SM. Myofibrillar protein synthesis following ingestion of soy protein isolate at rest and after resistance exercise in elderly men. Nutr Metab (Lond) 2012;9:57.

Figure Legend

Figure 1. Bi-phasic linear regression analyses of relative protein intake and rested myofibrillar protein synthesis in healthy older (A) and younger (B) men. Panel A: older adult protein intake relative to whole body mass; first segment described by y = 0.071x + 0.028; n = 48 points analyzed, r = 0.63; breakpoint at 0.40g/kg (95% CI 0.21-0.59g/kg). Panel B: younger adults protein intake relative to whole body mass; first segment described by y = 0.119x + 0.029; n = 93 points analyzed, r = 0.70; breakpoint at 0.25g/kg (95% CI 0.18-0.30 g/kg). According to the linear regression of the first line segment and estimated breakpoint, the peak myofibrillar protein synthesis rate was ~0.056 and ~0.058%/h in older and young men, respectively. The slope of the first segment of the bi-phasic regression was significantly different (P<0.05) between the older (0.071(%/h)/(g/kg), CI 0.039 to 0.103) and younger men (0.119(%/h)/(g/kg), CI 0.083 to 0.155). * P = 0.055 versus younger men.

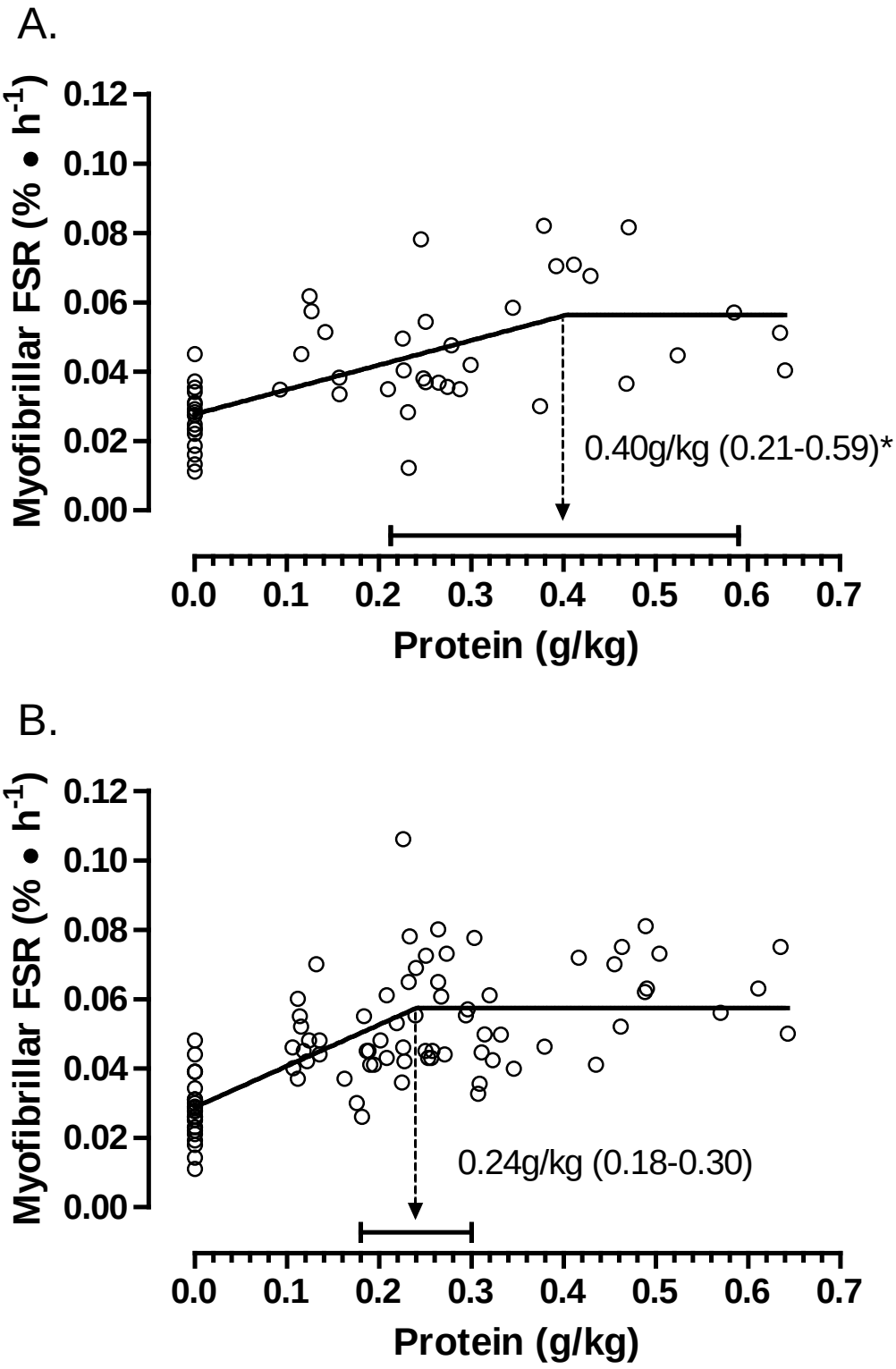
Table

Table 1: Subject characteristics.

	Elderly (n=43)	Young (n=65)	P-Value
Age (y)	71±1 (65-80)	22±4 (18-37)	<0.001
Body weight (kg)	79.3±4.1 (55.1-108.1)	79.9±2.5 (58.2-116.8)	0.65
Lean body mass (kg)*	54.5±2.8 (36.0-73.5)	65.9±1.8 (50.9-74.9)	<0.001
BMI (kg/m2)	25.7±1.0 (20.2-34.7)	25.1±0.7 (18.9-31.0)	0.49
Basal myofibrillar FSR (%/h)**	0.027±0.04 (0.011-0.045)	0.028±0.03 (0.011-0.048)	0.53

Mean±95%CI (range). *Lean body mass available for *n*=43 elderly and *n*=44 young subjects. **Basal (postabsorptive) myofibrillar FSR available for *n*=18 elderly and *n*=29 young subjects.

Figure


A.
Myofibrillar FSR (% • h-1)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.40g/kg (0.21-0.59)*
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Protein (g/kg)
B.
Myofibrillar FSR (% • h-1)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.24g/kg (0.18-0.30)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Protein (g/kg)